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(54) Dielectric laminated filter and communication apparatus

Dielektrisches laminiertes Filter und Übertragungsvorrichtung

Filtre diélectrique statifié et dispositif de communication

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EP-A- 0 641 035

- **PATENT ABSTRACTS OF JAPAN vol. 1996, no. 08, 30 August 1996 (1996-08-30) & JP 08 097603 A (KYOCERA CORP), 12 April 1996 (1996-04-12)**
- **PATENT ABSTRACTS OF JAPAN vol. 018, no. 675 (E-1648), 20 December 1994 (1994-12-20) & JP 06 268411 A (NGK INSULATORS LTD), 22 September 1994 (1994-09-22)**
- **G L MATTHAEI ET AL: "MICROWAVE FILTERS, IMPEDANCE-MATCHING NETWORKS, AND COUPLING STRUCTURES" , US,NEW YORK, MCGRAW-HILL, PAGE(S) 725-726 XP002091798**

EP 0 837 517 B1

Description

[0001] The present invention relates to a small dielectric laminated filter mainly used for a high frequency radio apparatus such as a portable telephone and a communication apparatus.

[0002] In recent years, many dielectric laminated filters have been used as high frequency filters for portable telephones. There is, however, a demand for further reduction of the size and thickness of such filters and attention is being paid to planar dielectric laminated filters that can be made thinner than a coaxial type.

[0003] An example of the above conventional dielectric laminated filter is described with reference to the drawings.

[0004] Figure 13 shows an exploded perspective view of a conventional dielectric laminated filter. Figure 14 shows a laminated body constituted by laminating the layers shown in Figure 13 which are dissembled, as seen from the direction shown by arrow A. Figure 15 is a cutaway cross sectional view in which the filter is cut along line D-D shown in Figure 13.

[0005] In Figures 13, 14, and 15, reference numerals 101, 102, 103, 104, 105, 106, and 107 designate dielectric sheets. Reference numerals 108a and 108b designate strip line electrodes formed on a dielectric sheet 105. Reference numerals 109a and 109b denote I/O line electrodes, 110a and 110b are notch capacitance electrodes, 111 is a coupling line electrode, and these inner electrodes are formed on the dielectric sheets 106, 104, and 102, respectively.

[0006] These dielectric sheets are laminated to form a dielectric laminated block on which shield electrodes 115 and 116 are formed on its top and bottom surfaces, respectively. I/O electrodes 117a and 117b and a ground electrode 118 are formed on the outer circumferential side of the dielectric laminated block.

[0007] The effects of the dielectric laminated filter configured as described above are described.

[0008] In the dielectric laminated filter shown in Figure 13, the shield electrodes 115 and 116 are grounded via the ground electrode 118. In addition, one end of each of the strip line electrodes 108a and 108b is grounded via the ground electrode 118 to constitute quarter-wavelength strip line resonators. The coupling line electrode 111 and the I/O line electrodes 109a and 109b act as a distributed constant line. A notch capacitance is provided between the notch capacity electrode 110a or 110b and the strip line electrode 108a or 108b. The notch capacitance electrodes 110a and 110b are connected together via the coupling line electrode 111 to connect the two strip line resonators in parallel via the notch capacity, and one ends of the I/O line electrodes 109a and 109b are connected to the notch capacitance electrodes 110a and 110b with the other ends connected to the I/O electrodes 117a and 117b in order to constitute a band elimination filter.

[0009] To prevent the electromagnetic coupling between the respective electrodes, for example, between the strip line electrodes 108a and 108b, earth electrodes 112, 113, and 114 are formed between the strip line electrodes 108a and 108b, between the I/O line electrodes 109a and 109b, and between the notch capacitance electrodes 110a and 110b, respectively.

[0010] To prevent the electromagnetic coupling between the strip line electrodes 108a and 108b and the coupling line electrode 111, a shield electrode 120 is formed on the dielectric sheet 103.

[0011] A dielectric laminated filter of this configuration is shown in, for example, Japanese Patent Application Laid-Open No. 6-268410.

[0012] Design, however, is complicated in this configuration because the electromagnetic coupling between the I/O line 109a or 109b and the strip line 108a or 108b cannot be prevented.

[0013] In addition, if dielectric sheets with a large dielectric constant to reduce the size of the filter, the electromagnetic coupling between the I/O and the coupling lines and the strip lines is further increased, thereby preventing a good band elimination filter characteristic from being obtained.

[0014] Furthermore, the conventional prevention of the electromagnetic coupling between the strip lines 108a and 108b using the earth electrode 112, the electromagnetic coupling between the notch capacitance electrodes 110a and 110b using the earth electrode 113, and the electromagnetic coupling between the I/O lines 109a and 109b using the earth electrode 114 is all imperfect and inductance is in fact provided in the earth electrodes 112, 113, and 114. Thus, unwanted electromagnetic coupling occurs between the strip line electrodes 108a and 108b and the earth electrode 112, between the I/O line electrodes 109a and 109b and the earth electrode 113, and between the notch capacitance electrodes 110a and 110b and the earth electrode 114.

[0015] Furthermore, the earth electrodes 112, 113, and 114 disturb the distribution of electromagnetic fields from the strip line electrodes 108a and 108b, the I/O line electrodes 109a and 109b, and the notch capacitance electrodes 110a and 110b to degrade the unloaded Q. As a result, a good band elimination filter characteristic cannot be achieved easily.

[0016] Reference JP-A-08 097603 describes a dielectric filter which is formed by a plurality of laminated dielectric layers. Input/output conductors are formed on the surface of an inner layer, and first and second inner conductors are formed on the surface of other inner layers. A shield layer is provided on the surface of a dielectric layer arranged between the layers of the first and second inner conductors.

[0017] EP-A-0 638 953 relates to a dielectric filter comprising a plurality of resonators formed on a multilayer dielectric substrate. Some of the inner layers have formed thereon a first, second and third resonator. These resonator layers are separated respectively by shielding layers.

[0018] JP-A-06 268411 describes a multi-layer filter which is formed by combining ten dielectric substrates. Resonance electrodes are provided on two of the inner layers. The resonance electrodes are connected by a connecting transmission line provided on a layer in between. Ground electrodes are formed on layers in between to provide a shielding layer between the resonators and the connection layer.

[0019] EP-A-0 641 035 describes a laminated dielectric filter having resonator electrodes provided on two of the inner layers. Shield electrode layers are arranged on intermediate layers and coupling capacitor electrodes are arranged on layers adjacent to the resonator layers.

[0020] In view of these problems of the conventional dielectric laminated filters, it is an object of this invention to provide a dielectric laminated filter and a communication apparatus that can achieve a much better band elimination filter characteristic compared to the prior art.

[0021] This is achieved by the features of claim 1.

[0022] According to this dielectric laminated filter a first and a second dielectric laminated blocks can be laminated via the shield electrodes to eliminate the unwanted electromagnetic coupling between strip line resonators and a coupling element, thereby enabling easy design. This filter also provides a good band elimination filter characteristic to increase the degree of freedom for design and can be made smaller by increasing the dielectric constant of dielectric sheets.

[0023] In addition, by connecting first, second, and third resonance electrodes together to form resonators, the wavelength can be increased without increasing the 'size of the laminated body, so the size of the resonators and thus the filter can be reduced.

[0024] Furthermore, by, for example, forming the third resonance electrodes of outer electrodes, the filter characteristics can be adjusted.

[0025] A dielectric laminated filter may further comprise said connection electrode which has a plurality of electrodes that are each formed on either of a pair of opposite surfaces among the outer surfaces and wherein said electrode is formed in an area other than the center of the surface.

[0026] The dielectric laminated filter can, for example, provide the same potential between shield electrodes and maintain a constant potential distribution within each shield electrode, thereby providing stable filter characteristics with excellent shielding.

[0027] A dielectric laminated filter may further comprise a shield electrode which is formed all over all the outer sides of said first dielectric laminated block other than the one on which said third resonance electrode is formed.

[0028] The dielectric laminated filter can, for example, improve the shielding of the first resonance electrodes with a large magnetic density to reduce radiation losses.

[0029] A dielectric laminated filter may further include an outer dielectric sheet laminated on an outer surface of said second shield electrode, wherein one end of said third resonance electrode which extends up to the top surface of said outer dielectric sheet.

[0030] The dielectric laminated filter can, for example, form ground capacities between the third resonance electrodes and the second shield electrodes to reduce the wavelength of the resonators.

[0031] In addition, by, for example, trimming the third resonance electrodes formed on the upper surface of the laminated body, the ground capacity can be varied to adjust the resonance frequency of the resonators. That is, this filter can absorb the dispersion of dielectric sheets and electrode patterns.

[0032] A dielectric laminated filter may comprise said second resonance electrode which has a larger width than said first resonance electrode.

[0033] A dielectric laminated filter may comprise said first and second dielectric blocks which have different thicknesses.

[0034] The dielectric laminated filter can, for example, abruptly vary like a step the impedance of the resonators, that is, can constitute SIR resonators to reduce the resonance frequency and thus the length of the resonators.

[0035] A dielectric laminated filter may comprise said first and second dielectric blocks which are formed of said dielectric sheets of different dielectric constants.

[0036] According to this dielectric laminated filter, for example, a first dielectric laminated block can comprise a material with a low dielectric constant while a second dielectric laminated block can comprise a material with a high dielectric constant in order to further reduce the unwanted coupling between the resonators and the coupling element without increasing their sizes.

[0037] In addition, this filter enables dielectric sheets with different materials to be laminated via the shield electrodes to reduce changes in material due to the chemical coupling between the different materials. Thus, it enables different materials to be laminated easily, compared to the prior art.

[0038] A dielectric laminated filter may include open stubs connected to said coupling element in parallel to attenuate high-order harmonic bands.

[0039] The dielectric laminated filter can have built-in LPF (Low Pass Filter) functions to reduce the size of the multi-functional filter and to reduce losses.

[0040] By separating resonance electrodes from I/O lines using the shield electrodes, the dielectric laminated filter can prevent the electromagnetic coupling between the resonance electrodes and the I/O lines, thereby enabling easy design. This filter can also provide a good band elimination filter characteristic to increase the degree of freedom for design and can be made smaller by increasing the dielectric constant of the dielectric sheets.

[0041] The dielectric laminated filter can, for example, appropriately combine the electromagnetic coupling between the resonators with the coupling line electrode to

achieve elliptic function characteristics in order to make the attenuation curve steeper compared to Chebyshev's characteristics that do not use the electromagnetic coupling between the resonators. Although insertion losses in the specific attenuation band would be decreased, insertion losses in the pass band could be further improved. Thus, the attenuation band can be increased without providing a multi-stage filter, thereby reducing the size of the filter and thus losses (improving the performance).

[0042] A communication apparatus of the present invention comprises a signal processing means using the dielectric laminated filter according to any of the present inventions; and an output means for outputting said processed signal.

Figure 1 is an exploded perspective view of a dielectric laminated filter according to a first and a second embodiments of this invention.

Figure 2 is a perspective view of the dielectric laminated filter according to the first and the second embodiments of this invention.

Figure 3 is an equivalent circuit diagram of the dielectric laminated filter according to the first and the second embodiments of this invention.

Figure 4 is an exploded perspective view of a dielectric laminated filter according to a third embodiment of this invention.

Figure 5 is a perspective view of the dielectric laminated filter according to the third embodiment of this invention.

Figure 6 is an equivalent circuit diagram of the dielectric laminated filter according to the third embodiment of this invention.

Figure 7 is an exploded perspective view of a dielectric laminated filter according to a fourth embodiment of this invention.

Figure 8 is a perspective view of the dielectric laminated filter according to the fourth embodiment of this invention.

Figure 9 is an equivalent circuit diagram of the dielectric laminated filter according to the fourth embodiment of this invention.

Figure 10 is an exploded perspective view of a dielectric laminated filter according to a fifth embodiment of this invention.

Figure 11 is a perspective view of the dielectric laminated filter according to the fifth embodiment of this invention.

Figure 12 is an equivalent circuit diagram of the dielectric laminated filter according to the fifth embodiment of this invention.

Figure 13 is an exploded perspective view of a conventional dielectric laminated film.

Figure 14 is an explanatory drawing showing the conventional dielectric laminated filter as seen from the direction shown by arrow A.

Figure 15 is a cutaway cross sectional view in which the conventional dielectric laminated filter is cut along line D-D.

Figure 16 is a graph showing the frequency characteristic of a dielectric laminated filter experimentally manufactured in the third embodiment.

Figure 17 is a graph comparing an elliptic function characteristic and a Chebyshev's characteristic in a band elimination filter.

Figures 18A to 18F are graphs describing the elliptic function characteristic in this invention.

Description of the Reference Numerals

[0043]

1, 2, 3, 4, 5 ... Dielectric sheet
6a, 6b ... First strip line electrode
7a, 7b ... Second strip line electrode
8a, 8b ... Notch capacity electrode
9a, 9b ... I/O line electrode
10 ... Coupling line electrode
11 ... First shield electrode
12 ... Laminated body
13 ... Second shield electrode
14 ... Third shield electrode
15a, 15b ... Third strip line electrode
16a, 16b ... Connection electrode
17a, 17b ... I/O electrode
18 ... Ground electrode
20a, 20b ... Notch capacity element
21a, 21b ... Tip shorting strip line resonator

[0044] The dielectric laminated filters according to the embodiments of this invention are described below with reference to the drawings.

(Embodiment 1)

[0045] Figure 1 is an exploded perspective view of a dielectric laminated filter according to one embodiment of this invention. Figure 2 is a perspective view of the dielectric laminated filter according to this embodiment (simply referred to as a "laminated body"). Figure 3 shows an equivalent circuit of the dielectric laminated filter according to this embodiment.

[0046] In Figures 1 and 2, reference numerals 1, 2, 3, 4, and 5 designate dielectric sheets. These dielectric sheets comprise dielectric ceramic of the same material that has been formed into a green sheet and that can be sintered at a low temperature (εr = 7 to 100. εr is a dielectric constant).

[0047] Reference numerals 6a and 6b indicate first strip line electrodes corresponding to first resonance electrodes according to this invention. The first strip line electrodes 6a and 6b are formed on the top surface of the dielectric sheet 2, extend from one side to the other, and are disposed in parallel to each other. Reference numerals 7a and 7b indicate second strip line electrodes

corresponding to second resonance electrodes according to this invention, are formed on the top surface of the dielectric sheet 4, and extend from one side to the other of the dielectric sheet 4. Reference numerals 8a and 8b denote notch capacitance electrodes, 9a and 9b are I/O line electrodes, and 10 is a coupling line electrode. All these electrodes are formed on the top surface of the dielectric sheet 5. The notch capacitance electrodes 8a and 8b are formed opposite to the second strip line electrodes 7a and 7b. The I/O line electrodes 9a and 9b and the coupling line electrode 10 are formed in positions such that they are not opposed to the second strip line electrodes 7a and 7b. One end of the I/O line electrode 9a and one end of the coupling line electrode 10 are connected to the notch capacitance electrode 8a, and one end of the I/O line electrode 9b and the other end of the coupling line electrode 10 are connected to the notch capacity electrode 8b. Reference numeral 11 denotes a first shield electrode formed on the top surface of the dielectric sheet 3.

[0048] In this manner, these inner electrodes formed in the internal layers of the laminated body have electrode patterns printed thereon using metallic paste such as silver, copper, or gold having a high conductivity.

[0049] Furthermore, 12 is the laminated body formed by laminating the dielectric sheets 5, 4, 3, 2, and 1 in this order, pressing them, and simultaneously sintering each dielectric sheet and each inner electrode.

[0050] Of course, a plurality of dielectric laminated filters may be simultaneously manufactured from the same laminated body. In this case, a cutting process for cutting the laminated body into a plurality of laminated body pieces is required between the pressing process and the sintering process. These cut laminated body pieces correspond to the dielectric laminated filter.

[0051] In addition, 13 is a second shield electrode, 14 is a third shield electrode, and these electrodes are formed almost all over the top and the bottom surfaces of the laminated body 12, respectively. Reference numerals 15a and 15b are third strip line electrodes corresponding to third resonance electrodes according to this invention. The third strip line electrodes 15a and 15b are formed on one of the outer circumferential sides of the laminated body 12. The third strip line electrode 15a is connected to one end of the first strip line electrode 6a and one end of the second strip line electrode 7a. The third strip line electrode 15b is connected to one end of the first strip line electrode 6b and one end of the second strip line electrode 7b. Reference numerals 16a and 16b are connection electrodes formed on the two opposite outer circumferential sides of the laminated body 12 and connected to each of the shield electrodes 11, 13, and 14. Reference numerals 17a and 17b are I/O electrodes formed on the two outer circumferential sides of the laminated body 12. The I/O electrode 17a is connected to the other end of the I/O line electrode 9a and the I/O electrode 17b is connected to the other end of the I/O line electrode 9b. Reference numeral 18 is a ground terminal formed on one of the outer circumferential sides of the laminated body 12 and connected to the other end of each of the shield electrodes 11, 13, and 14 and the other ends of the first strip line electrodes 6a and 6b. In this manner, the outer electrodes formed on the external surfaces of the laminated body are formed by printing or plating electrode patterns using metallic paste such as silver, copper, or gold having a high conductivity. The first dielectric laminated block according to this invention corresponds to a block including the dielectric sheets 1 and 2. The second dielectric laminated block according to this invention corresponds to a block including the dielectric sheets 3, 4, and 5.

[0052] The dielectric laminated filter of this configuration is further described with reference to Figures 1, 2, and 3.

[0053] The other ends of the first strip line electrodes 6a and 6b are grounded via the ground electrode 18 to constitute tip shorting strip line resonators 21a and 21b that use the other ends of the second strip line electrodes 7a and 7b as open ends. In addition, the notch capacitance electrodes 8a and 8b are formed opposite to the second strip line electrodes 7a and 7b to constitute the notch capacity elements 12a and 12b. Furthermore, the I/O line electrodes 9a and 9b and the coupling line electrode 10 act as coupling elements for distributed constant lines. Thus, by connecting the I/O line electrodes 9a and 9b and the coupling line electrode 10 to the notch capacitance electrodes 8a and 8b as described above, the tip shorting strip line resonators 21a and 21b are connected in parallel via the notch capacity elements 20a and 20b as shown in the equivalent circuit diagram in Figure 3. This allows a band elimination filter using the I/O electrodes 17a and 17b as I/O terminals to be provided.

[0054] As described above, this embodiment can laminate via the first shield electrode 11, the first dielectric laminated block including the first strip line electrodes 6a and 6b and the second dielectric laminated block including the second strip line electrodes 7a and 7b and coupling elements in order to prevent the unwanted electromagnetic coupling between the first strip line electrodes 6a and 6b and the I/O line electrodes 9a and 9b acting as the coupling elements and between the first strip line electrodes 6a and 6b and the coupling line electrode 10.

[0055] The important point of this embodiment is the use of the structure in which the tip shorting strip line resonators 21a and 21b use the other ends of the second strip line electrodes 7a and 7b as open ends. This structure causes a field distribution to dominate in the second strip line electrodes, thereby allowing the magnetic coupling within the second dielectric laminated block to be neglected. In other words, the field coupling between the second strip line electrodes 7a and 7b and the notch capacitance electrodes 8a and 8b is used to form the notch capacity elements 20a and 20b (see Figure 3).

[0056] Furthermore, by disposing the I/O line electrodes 9a and 9b and the coupling line electrode 10 in such a way that they are not opposed to the second strip line electrodes 7a and 7b, the unwanted field coupling with the second strip line electrodes 7a and 7b can be reduced to a negligible magnitude.

[0057] As described above, the unwanted field coupling between the resonators (that is, the tip shorting strip line resonators 21a and 21b) and the I/O lines (that is, the I/O line electrodes 9a and 9b) and between the resonators and the coupling element (that is, the coupling line electrode 10) can be reduced to a negligible magnitude, thereby enabling easy design and providing a good band elimination filter characteristic.

[0058] In addition, by appropriately combining the electromagnetic coupling between the resonators with the coupling line electrode 10 to achieve an elliptic function characteristic, a steep attenuation characteristic curve can be obtained compared to a Chebychev's characteristic 404 that does not use the electromagnetic coupling M between the resonators, as shown in Figure 17.

[0059] For example, Figures 18A to 18F show the transmission characteristic of a band elimination filter in which two strip line resonators are connected in parallel using a coupling line.

[0060] Figure 18A is a graph showing a transmission characteristic obtained when the coupling line has an impedance of 50Ω and a line length of a quarter wavelength at 1.5 GHz if there is no electromagnetic coupling between the resonators.

[0061] Figure 18B is a graph that is the same as Figure 27A except that the resonance frequency is offset.

[0062] Figure 18C is a graph that is the same as Figure 27B except that the coupling line length is a one-eighth wavelength at 1.5 GHz.

[0063] Figure 18D is a graph that is the same as Figure 27A except that there is electromagnetic coupling between the resonators.

[0064] Figure 18E is a graph that is the same as Figure 27D except that the coupling line length is a one-eighth wavelength at 1.5 GHz.

[0065] Figure 18F is a graph that is the same as Figure 27E except that the gap between the resonators is expanded to reduce the electromagnetic coupling.

[0066] As described above, changes in characteristic occurring when the coupling line is changed depend on whether or not there is electromagnetic coupling between the resonators (see Figures 18C and 18E. Consequently, to realize a steep elliptic function characteristic in the band elimination filter according to this embodiment, the behavior of the characteristic must be comprehensively considered in design.

[0067] Insertion losses can be reduced in a pass band 402 used to obtain a desired attenuation band 401 and attenuation amount. Thus, the attenuation band 401 can be expanded without providing a multi-stage filter, thereby reducing the size of the filter and losses (increasing the performance).

[0068] If, for example, the line length of the coupling line cannot be configured to be a one-eighth wavelength or more due to a geometrical constraint, the electromagnetic coupling between the resonators can be combined together as shown in Figure 18F to achieve an elliptic function characteristic with a steep attenuation characteristic curve.

[0069] That is, by appropriately combining the electromagnetic coupling M between the resonators with the coupling line electrode 10, coupling elements can be provided which have an impedance and a wavelength that cannot be configured only by the coupling line electrode 10 due to a geometrical constraint.

[0070] Thus, by eliminating unwanted electromagnetic coupling and using the electromagnetic coupling between the resonators, the degree of freedom can be increased and the dielectric constant of the dielectric sheets can be increased, thereby reducing the size of the resonators and improving the performance. Due to the active use of the electromagnetic coupling between the resonators, as described above, this embodiment has between the strip line electrodes 6a and 6b no earth electrode such as that described in the conventional dielectric laminated filter. An electromagnetic coupling prevention member according to this invention corresponds to the earth electrode.

[0071] In addition, the thickness of the dielectric sheet 4 can be reduced to reduce the area of the second strip line electrodes 7a and 7b and notch capacitance electrodes 8a and 8b used to constitute the desired notch capacity elements 20a and 20b in order to increase the area used to form the coupling element without disposing it opposite to the second strip line electrodes 7a and 7b, thereby further increasing the degree of freedom in design.

[0072] Furthermore, by folding and connecting the first, the second, and the third strip line electrodes together to form the tip shorting strip line resonators 21a and 21b, the wavelength of the resonators can be increased without increasing the size of the laminated body, thereby reducing the size of the tip shorting strip line resonators 21a and 21b.

[0073] In addition, filter characteristics can be adjusted by forming the third strip line electrodes 15a and 15b of outer electrodes. That is, a trimming grinder or the like can be used to trim the third strip line electrodes 15a and 15b to adjust the interval between the electrodes in order to vary the electromagnetic coupling between the third strip line electrodes 15a and 15b, thereby allowing the attenuation band width within the band elimination filter characteristics to be adjusted.

[0074] By forming the connection electrodes 16a and 16b at the respective ends of the two opposite outer circumferential sides of the laminated body 12 and connecting the connection electrodes to each of the shield electrodes 11, 13, and 14, the same potential can be provided between the shield electrodes with a constant

potential distribution maintained within each shield electrode, thereby providing stable filter characteristics with excellent shielding. These effects are significant at a frequency of more than 1 GHz.

[0075] Therefore, a small adjustable dielectric laminated filter that can be designed easily can be realized.

(Embodiment 2)

[0076] A dielectric laminated filter according to this embodiment is described below with reference to the drawings.

[0077] The structure of the dielectric laminated filter according to this embodiment is almost the same as that in the first embodiment except that the first and the second dielectric laminated blocks are formed of dielectric sheets of different dielectric constants.

[0078] That is, the dielectric constant of the dielectric sheets 1 and 2 differs from that of the dielectric sheets 3, 4, and 5.

[0079] As describe above, this embodiment not only has the same effects as the first embodiment but, compared to the first embodiment, can also reduce the unwanted electromagnetic coupling between the resonators and the I/O lines and between the resonators and the coupling element without increasing the size of the dielectric laminated filter by making the dielectric sheets 1 and 2 of a material of a low dielectric constant and making the dielectric sheets 3, 4, and 5 of a material of a high dielectric constant.

[0080] In addition, the dielectric sheets 2 and 3 of different materials can be laminated via the first shield electrode to reduce changes in material caused by the chemical binding between different materials, thereby enabling different materials to be laminated easily, compared to the prior art.

(Embodiment 3)

[0081] A third embodiment of this invention is described below with reference to the drawings.

[0082] Figure 4 is an exploded perspective view of a dielectric laminated filter according to this embodiment of the invention. Figure 5 is a perspective view of a dielectric body according to this embodiment. Figure 6 shows an equivalent circuit of the dielectric laminated filter according to this embodiment.

[0083] As shown in Figures 4 and 5, the structure of this dielectric laminated filter is the same as that in the first embodiment except for the following points.

[0084] The second and the third shield electrodes 13 and 14 are formed as inner electrode and dielectric sheets 41 and 42 are laminated on the top and the bottom surfaces to form a laminated body 45. The third strip line electrodes 15a and 15b are formed to extend up to the top surface of the dielectric sheet 41.

[0085] As describe above, this embodiment not only has the same effects as the first embodiment but can also reduce the resonance frequency of the tip shorting strip line resonators 21a and 21b (see Figure 6) by extending the third strip line electrodes 15a and 15b up to the top surface of the dielectric sheet 41 to form ground capacity elements 44a and 44b between the third strip line electrodes 15a and 15b and the second shield electrode 13. Consequently, the length of the tip shorting strip line resonators 21a and 21b, that is, the wavelength can be reduced.

[0086] In addition, by trimming partial line electrodes 43a and 43b that are formed on the top surface of the dielectric sheet 41 and that are part of the third strip line electrodes 15a and 15b, the capacity (capacitance) of the ground capacity elements 44a and 44b can be varied to adjust the resonance frequency of the tip shorting strip line resonators 21a and 21b. This adjustment can be normally provided in the middle of a manufacturing process to absorb the dispersion of dielectric sheets and electrode patterns, thereby improving the yield.

[0087] Furthermore, if the connection electrodes 16a and 16b, the I/O electrodes 17a and 17b, and the ground electrode 18 are extended up to the top surface of the dielectric sheet 41 and the bottom surface of the dielectric sheet 42 and if the laminated body is mounted on a substrate by reflow soldering, the solder can be more effectively attached to each electrode surface and firmly mounted, thereby improving the reliability of mounting.

[0088] Therefore, a small dielectric laminated filter that has higher designability and adjustability than the first embodiment can be realized.

[0089] Figure 16 is a graph showing the frequency characteristic of a dielectric laminated filter experimentally manufactured according to this embodiment. Dielectric sheets with a dielectric constant of $\varepsilon r = 58$ were used and the laminated body 45 had a size of $4.5 \times 3.2 \times 2.0$ mm. The electromagnetic coupling between the resonators and the coupling line electrode 10 were, as described above, appropriately combined together to achieve an elliptic function characteristic 160 such as that shown in Figure 23.

(Embodiment 4)

[0090] A fourth embodiment of this invention is described below with reference to the drawings.

[0091] Figure 7 is an exploded perspective view of a dielectric laminated filter according to this embodiment of the invention. Figure 8 is a perspective view of a dielectric body according to this embodiment. Figure 9 shows an equivalent circuit of the dielectric laminated filter according to this embodiment.

[0092] As shown in Figures 7 and 8, the structure of this dielectric laminated filter is the same as that in the first embodiment except for the following points.

[0093] The second shield electrode 13 is formed all over the surface of the laminated body 12. The ground electrode 18 is formed all over one of the outer circumferential sides of the laminated body 12. A fourth shield

electrode 71 is formed all over two opposite sides of the dielectric sheets 1 and 2 to connect the connection electrodes 16a and 16b to the fourth shield electrode 71. In addition, the line width of the second strip line electrodes 7a and 7b is formed to be larger than that of the first strip line electrodes 6a and 6b.

[0094] As described above, this embodiment not only has the same ef fects as the first embodiment but also improves the shielding capability of the first strip line electrodes 6a and 6b with a large magnetic density to reduce radiation losses because the shield electrode is formed all over the top surface and all the outer circumferential sides of the first dielectric laminated block other than the one on which the third strip line electrodes 15a and 15b are formed, the first dielectric laminated block including the dielectric sheets 1 and 2 and the first strip line electrodes 6a and 6b. As a result, the unloaded Q of the tip shorting strip line resonators 21a and 21b (see Figure 9) can be improved to realize a high performance dielectric laminated filter.

[0095] The line width of the second strip line electrodes 7a and 7b is formed to be larger than that of the first strip line electrodes 6a and 6b in order to cause the impedance of the tip shorting strip line resonators 21a and 21b to be abruptly varied like a step. This provides SIR resonators to enable the resonance frequency and the length of the resonators to be reduced in order to realize a small dielectric laminated filter.

(Embodiment 5)

[0096] A fifth embodiment of this invention is described below with reference to the drawings.

[0097] Figure 10 is an exploded perspective view of a dielectric laminated filter according to this embodiment of the invention. Figure 11 is a perspective view of a dielectric body according to this embodiment. Figure 12 shows an equivalent circuit of the dielectric laminated filter according to this embodiment.

[0098] The structure in Figures 10 and 11 is the same as that in the first embodiment except for the following points. First, open stubs 31a and 31b are formed on the top surface of the dielectric sheet 5 to connect the I/O line electrodes 9a and 9b in parallel. Second, the second dielectric block has a smaller thickness than the first dielectric block.

[0099] As described above, this embodiment not only has the same effects as the first embodiment but can also size the open stubs 31a and 31b so as to have a length equal to a quarter wavelength at frequencies double and triple the fundamental pass band to form an attenuating pole at these frequencies. This attenuating pole is effective in attenuating a second and a third harmonic bands and enables an attenuating pole to be formed without affecting the characteristics of the fundamental frequency band.

[0100] In addition, the thickness of the second dielectric block (corresponding to the laminated portion including the dielectric sheets 3, 4, and 5) can be reduced below that of the first dielectric block (corresponding to the laminated portion including the dielectric sheets 1 and 2) to reduce the impedance of the second strip line electrodes 7a and 7b below that of the first strip line electrodes 6a and 6b, thereby enabling the impedance of the tip shorting strip line resonators 21a and 21b to be abruptly varied like a step. That is, SIR resonators can be provided to reduce the resonance frequency and thus the length of the resonators.

[0101] Consequently, this embodiment can attenuate high-order harmonic bands without the need to add an LPF, thereby reducing the size and losses of the multifunctional filter. Due to its ability to reduce the length of the resonators, this embodiment can realize a much smaller dielectric laminated filter.

[0102] The communication apparatus comprises, for example, a receipt means for receiving a radio signal from a source; a signal processing means comprising the dielectric laminated filter described in any of the above embodiments to extract a predetermined portion from the received signal and processing it; an output means for outputting the processed signal to a speaker, and a signalling means for issuing a signal to the source. Of course, the signalling means can be omitted from the communication apparatus.

[0103] The above embodiments can provide a small high-performance dielectric laminated filter that can be designed easily and that enables the resonance frequency of the filter and the electromagnetic coupling between resonators to be adjusted during a manufacturing process.

[0104] Although the above embodiments have been described in conjunction with the two strip lines formed on the same dielectric sheet, this invention is not limited to this aspect and three strip lines may be formed thereon. In this case, two coupling line electrodes are required and connected in series.

Claims

1. A dielectric laminated band elimination filter, comprising:

    a first dielectric laminated block in which a plurality of dielectric sheets (1, 2) are laminated,

    a plurality of first strip line electrodes (6a, 6b) formed on an inner layer (2) of said first dielectric laminated block,

    a second dielectric laminated block in which a plurality of dielectric sheets (3, 4, 5) is laminated,

    a plurality of second strip line electrodes (7a, 7b) formed on an inner layer (4) of said second

dielectric laminated block,

at feast two I/O line electrodes (9a, 9b) formed on another inner layer (5) of said second laminated block,

a shield electrode (11) formed between said first dielectric laminated block and said second dielectric laminated block

characterized in that
said dielectric laminated band elimination filter further comprises at least one coupling line electrode (10) and a plurality of notch capacitance electrodes (8a, 8b) formed on the other inner layer (5) of said second laminated block, wherein said coupling line electrode (10), said notch capacitance electrodes (8a, 8b) and said I/O line electrodes (8a, 8b) are electrically connected in series,
said respective first strip line electrodes (6a, 6b) and said respective second strip line electrodes (7a, 7b) are electrically connected to form a plurality of resonators, and
said respective second strip line electrodes (7a, 7b) and said respective notch capacitance electrodes (8a, 8b) are opposed to form a plurality of notch capacitance elements (20a, 20b).

2. A dielectric laminated band elimination filter according to claim 1, further comprising a plurality of connection electrodes (15a, 15b), wherein said connection electrodes (15a, 15b) are formed on a side surface and connect said respective first strip lines electrodes (6a, 6b) and said respective second strip lines (7a, 7b) electrically.

3. A dielectric laminated band elimination filter according to claim 2, further comprising shield electrodes (13, 14, 18) which cover almost all of the outer surface except for the surface on which said connection electrodes (15a, 15b) are formed.

4. A dielectric laminated band elimination filter according to any of claims 1 to 3, wherein said second strip line electrodes (7a, 7b) have a larger width than the width of said first strip line electrodes (6a, 6b).

5. A dielectric laminated band elimination filter according to any of claims 1 to 4, wherein said first and second dielectric laminated blocks have different thicknesses.

6. A dielectric laminated band elimination filter according to any of claims 1 to 5, wherein said first and second dielectric blocks are formed of said dielectric sheets of different dielectric constants.

7. A dielectric laminated band elimination filter according to any of claims 1 to 6, including open stubs (31a, 31b) connected to said I/O line electrodes (9a, 9b) to attenuate higher order harmonic bands.

8. A dielectric laminated band elimination filter according to any of claims 1 to 7, wherein resonance frequencies of said resonators are offset to each other.

9. A dielectric laminated band elimination filter according to any of claims 1 to 8, wherein said shield electrode (11) covers all of said first strip line electrodes (6a, 6b) except for the open ends of said first strip line electrodes (6a, 6b) in such a manner that said shield electrode (11) prevents a coupling between said first strip line electrodes (6a, 6b) and said coupling line electrode (10), and between said first strip line electrodes (6a, 6b) and said I/O line electrodes (9a, 9b), and open ends of said respective second strip line electrodes (7a, 7b) and said respective notch capacitance electrodes (8a,8b) are opposed to form a plurality of notch capacitance elements (20a, 20b).

10. A dielectric laminated band elimination filter according to claim 2 or 3, wherein the material of the electrodes (6a, 6b, 7a, 7b) formed in the inner layers of the dielectric laminated band elimination filter is different from that of the electrodes (15a, 15b) formed outside said dielectric laminated band elimination filter.

11. A communication apparatus comprising:

a receiver means for receiving a signal;

a signal processing means using a dielectric laminated band elimination filter in accordance with any of claims 1 to 10, and

an output means for outputting a processed signal.

Patentansprüche

1. Dielektrisches geschichtetes Bandsperrfilter umfassend:

einen ersten dielektrischen geschichteten Block mit einer Mehrzahl geschichteter dielektrischer Platten (1, 2),
eine Mehrzahl erster Leiterbahnelektroden (6a, 6b), die auf einer inneren Schicht (2) des ersten dielektrischen geschichteten Blocks gebildet sind,
einen zweiten geschichteten dielektrischen geschichteten Block mit einer Mehrzahl geschichteter dielektrischer Platten (3, 4, 5),

eine Mehrzahl von zweiten Leiterbahnelektroden (7a, 7b), die auf einer inneren Schicht (4) des zweiten dielektrischen geschichteten Blocks gebildet sind,

zumindest zwei Eingabe/Ausgabe-Leitungselektroden (9a, 9b), die auf einer anderen inneren Schicht (5) es zweiten geschichteten Blocks gebildet sind,

eine Schirmelektrode (11), die zwischen dem ersten dielektrischen geschichteten Block und dem zweiten dielektrischen geschichteten Block gebildet ist,

dadurch gekennzeichnet, dass

das dielektrische geschichtete Bandsperrfilter außerdem zumindest eine Kopplungsleitungselektrode (10) und eine Mehrzahl von Dämpfungskapazitätselektroden (8a, 8b) umfasst, die auf der anderen inneren Schicht (5) des zweiten geschichteten Blocks gebildet sind, wobei die Kopplungsleitungselektrode (10), die Dämpfungskapazitätselektroden (8a, 8b) und die Eingabe/Ausgabe-Leitungselektroden (8a, 8b) elektrisch in Reihe geschaltet sind,

die jeweiligen ersten Leiterbahnelektroden (6a, 6b) und die jeweiligen zweiten Leiterbahnelektroden (7a, 7b) elektrisch verbunden sind, um eine Mehrzahl von Resonatoren zu bilden, und

die jeweiligen zweiten Leiterbahnelektroden (7a, 7b) und die jeweiligen Dämpfungskapazitätselektroden (8a, 8b) gegenüberliegend angeordnet sind, um eine Mehrzahl von Dämpfungskapazitätselementen (20a, 20b) zu bilden.

2. Dielektrisches geschichtetes Bandsperrfilter nach Anspruch 1, das außerdem eine Mehrzahl von Verbindungselektroden (15a, 15b) umfasst, wobei die Verbindungselektroden (15a, 15b) auf einer Seitenoberfläche gebildet sind und die jeweiligen ersten Leiterbahnelektroden (6a, 6b) und die jeweiligen zweiten Leiterbahnelektroden (7a, 7b) elektrisch verbinden.

3. Dielektrisches geschichtetes Bandsperrfilter nach Anspruch 2, das außerdem Schirmelektroden (13, 14, 18) umfasst, die fast die gesamte äußere Oberfläche mit der Ausnahme der Oberfläche bedecken, auf der die Verbindungselektroden (15a, 15b) gebildet sind.

4. Dielektrisches geschichtetes Bandsperrfilter nach einem der Ansprüche 1 bis 3, wobei die zweiten Leiterbahnelektroden (7a, 7b) eine größere Breite aufweisen, als die Breite der ersten Leiterbahnelektroden (6a, 6b).

5. Dielektrisches geschichtetes Bandsperrfilter nach einem der Ansprüche 1 bis 4, wobei der erste und der zweite dielektrische geschichtete Block unterschiedliche Dicken aufweisen.

6. Dielektrisches geschichtetes Bandsperrfilter nach einem der Ansprüche 1 bis 5, wobei der erste und der zweite dielektrische Block aus dielektrischen Platten unterschiedlicher dielektrischer Konstanten gebildet sind.

7. Dielektrisches geschichtetes Bandsperrfilter nach einem der Ansprüche 1 bis 6, mit offenen Blindleitungen (31a, 31b), die mit den Eingangs/Ausgangs-Leitungselektroden (9a, 9b) verbunden sind, um harmonische Bänder höherer Ordnung abzuschwächen.

8. Dielektrisches geschichtetes Bandsperrfilter nach einem der Ansprüche 1 bis 7, wobei Resonanzfrequenzen der Resonatoren zueinander versetzt sind.

9. Dielektrisches geschichtetes Bandsperrfilter nach einem der Ansprüche 1 bis 8, wobei die Schirmelektrode (11) die gesamten ersten Leiterbahnelektroden (6a, 6b) mit der Ausnahme der offenen Enden der ersten Leiterbahnelektroden (6a, 6b) bedecken, so dass die Schirmelektrode (11) eine Kopplung zwischen den ersten Leiterbahnelektroden (6a, 6b) und der Kopplungsleitungselektrode (10) und zwischen den ersten Leiterbahnelektroden (6a, 6b) und den Eingangs/Ausgangs-Leitungselektroden (9a, 9b) verhindert, und offene Enden der jeweiligen zweiten Leiterbahnelektroden (7a, 7b) und der jeweiligen Dämpfungskapazitätselektroden (8a, 8b) gegenüberliegend angeordnet sind, um eine Mehrzahl von Dämpfungskapazitätselementen (20a, 20b) zu bilden.

10. Dielektrisches geschichtetes Bandsperrfilter nach Anspruch 2 oder 3, wobei das Material der Elektroden (6a, 6b, 7a. 7b), die auf den inneren Schichten des dielektrisch geschichteten Bandsperrfilters gebildet sind, unterschiedlich von dem der Elektroden (15a, 15b) ist, die außerhalb des dielektrisch geschichteten Bandsperrfilters gebildet sind.

11. Kommunikationsvorrichtung umfassend:

eine Empfangseinrichtung zum Empfang eines Signals;

eine Signalverarbeitungseinrichtung, die ein dielektrisch geschichtetes Bandsperrfilter nach einem der Ansprüche 1 bis 10 verwendet, und

eine Ausgabeeinrichtung zur Ausgabe eines verarbeiteten Signals.

Revendications

1. Un filtre stratifié diélectrique à élimination de bande, comprenant :

   un premier bloc stratifié diélectrique dans lequel une pluralité de feuilles diélectriques (1, 2) sont stratifiées,

   une pluralité de premières électrodes de ligne à microbande (6a, 6b), formées sur une couche interne (2) dudit premier bloc stratifié diélectrique,

   un second bloc stratifié diélectrique dans lequel une pluralité de feuilles diélectriques (3, 4, 5) sont stratifiées,

   une pluralité de secondes électrodes de ligne à microbande (7a, 7b) formées sur une couche interne (4) dudit second bloc stratifié diélectrique,

   au moins deux électrodes de ligne d'entrée/sortie (9a, 9b) formées sur une autre couche interne (5) dudit second bloc stratifié,

   une électrode de blindage (11) formée entre ledit premier bloc stratifié diélectrique et ledit second bloc stratifié diélectrique,

   Caractérisé en ce que
   Ledit filtre stratifié diélectrique à élimination de bande comprend, en outre, au moins une électrode de ligne de couplage (10) et une pluralité d'électrodes capacitives coupe-bande à bande étroite (8a, 8b) formées sur l'autre couche interne (5) dudit second bloc stratifié, dans lequel ladite électrode de ligne de couplage (10), lesdites électrodes capacitives coupe-bande à bande étroite (8a, 8b) et lesdites électrodes de ligne d'entrée/sortie (8a, 8b) sont connectées électriquement en séries,
   lesdites premières électrodes de ligne à microbande respectives (6a, 6b) et lesdites secondes électrodes de ligne à microbande respectives (7a, 7b) sont connectées pour former une pluralité de résonateurs,
   lesdites secondes électrodes de ligne à microbande respectives (7a, 7b) et lesdites électrodes capacitives coupe-bande à bande étroite respectives (8a, 8b) sont opposées pour former une pluralité d'éléments capacitifs coupe-bande à bande étroite (20a, 20b),

2. Un filtre stratifié diélectrique à élimination de bande selon la revendication 1, comprenant, en outre, une pluralité d'électrodes de connexion (15a, 15b), dans lequel lesdites électrodes de connexion (15a, 15b) sont formées sur une surface latérale et connectent lesdites premières électrodes de ligne à microbande (6a, 6b) et lesdites secondes lignes à microbande respectives (7a, 7b) électriquement.

3. Un filtre stratifié diélectrique à élimination de bande selon la revendication 2, comprenant, en outre, des électrodes de blindage (13, 14, 18) qui recouvrent presque totalement la surface externe sauf la surface sur laquelle lesdites électrodes de connexion (15a, 15b) sont formées.

4. Un filtre stratifié diélectrique à élimination de bande selon l'une quelconque des revendications 1 à 3, dans lequel lesdites secondes électrodes de ligne à microbande (7a, 7b) présentent une largeur plus grande que la largeur desdites premières électrodes de ligne à microbande (6a, 6b).

5. Un filtre stratifié diélectrique à élimination de bande selon l'une quelconque des revendications 1 à 4, dans lequel lesdits premier et second blocs stratifiés diélectriques présentent des épaisseurs différentes.

6. Un filtre stratifié diélectrique à élimination de bande selon l'une quelconque des revendications 1 à 5, dans lequel lesdits premier et second bloc diélectriques sont formés desdites feuilles diélectriques de constantes diélectriques différentes.

7. Un filtre stratifié diélectrique à élimination de bande selon l'une quelconque des revendications 1 à 6, incluant des tronçons ouverts (31a, 31b) connectés auxdites électrodes de ligne d'entrée/sortie (9a, 9b) pour atténuer les bandes d'harmoniques d'ordre plus élevé.

8. Un filtre stratifié diélectrique à élimination de bande selon l'une quelconque des revendications 1 à 7, dans lequel les fréquences de résonance desdits résonateurs sont décalées les unes par rapport aux autres.

9. Un filtre stratifié diélectrique à élimination de bande selon l'une quelconque des revendications 1 à 8, dans lequel ladite électrode de blindage (11) couvre la totalité desdites premières électrodes de ligne à microbande (6a, 6b) sauf pour les extrémités ouvertes desdites premières électrodes de ligne à microbande (6a, 6b) de manière telle que ladite électrode de blindage (11) empêche un couplage entre lesdites premières électrodes de ligne à microbande (6a, 6b) et ladite électrode de ligne de couplage (10) et entre lesdites premières électrodes de ligne à microbande (6a, 6b) et lesdites électrodes de ligne d'entrée/sortie (9a, 9b), et les extrémités ouvertes desdites secondes électrodes de ligne à microban-

de respectives (7a, 7b), et lesdites électrodes capacitives coupe-bande à bande étroite respectives (8a, 8b) sont opposées pour former une pluralité d'éléments capacitifs coupe-bande à bande étroite (20a, 20b)

10. Un filtre stratifié diélectrique à élimination de bande selon la revendication 2 ou 3, dans lequel le matériau des électrodes (6a, 6b, 7a, 7b) formé dans les couches internes du filtre stratifié diélectrique à élimination de bande est différent de celui des électrodes (15a, 15b) formées à l'extérieur dudit filtre stratifié diélectrique à élimination de bande.

11. Un appareil de communication comprenant :

un moyen de récepteur pour recevoir un signal ;

un moyen de traitement du signal utilisant un filtre stratifié diélectrique à élimination de bande en conformité avec l'une quelconque des revendications 1 à 10, et

un moyen de sortie pour sortir un signal traité.

F i g. 1

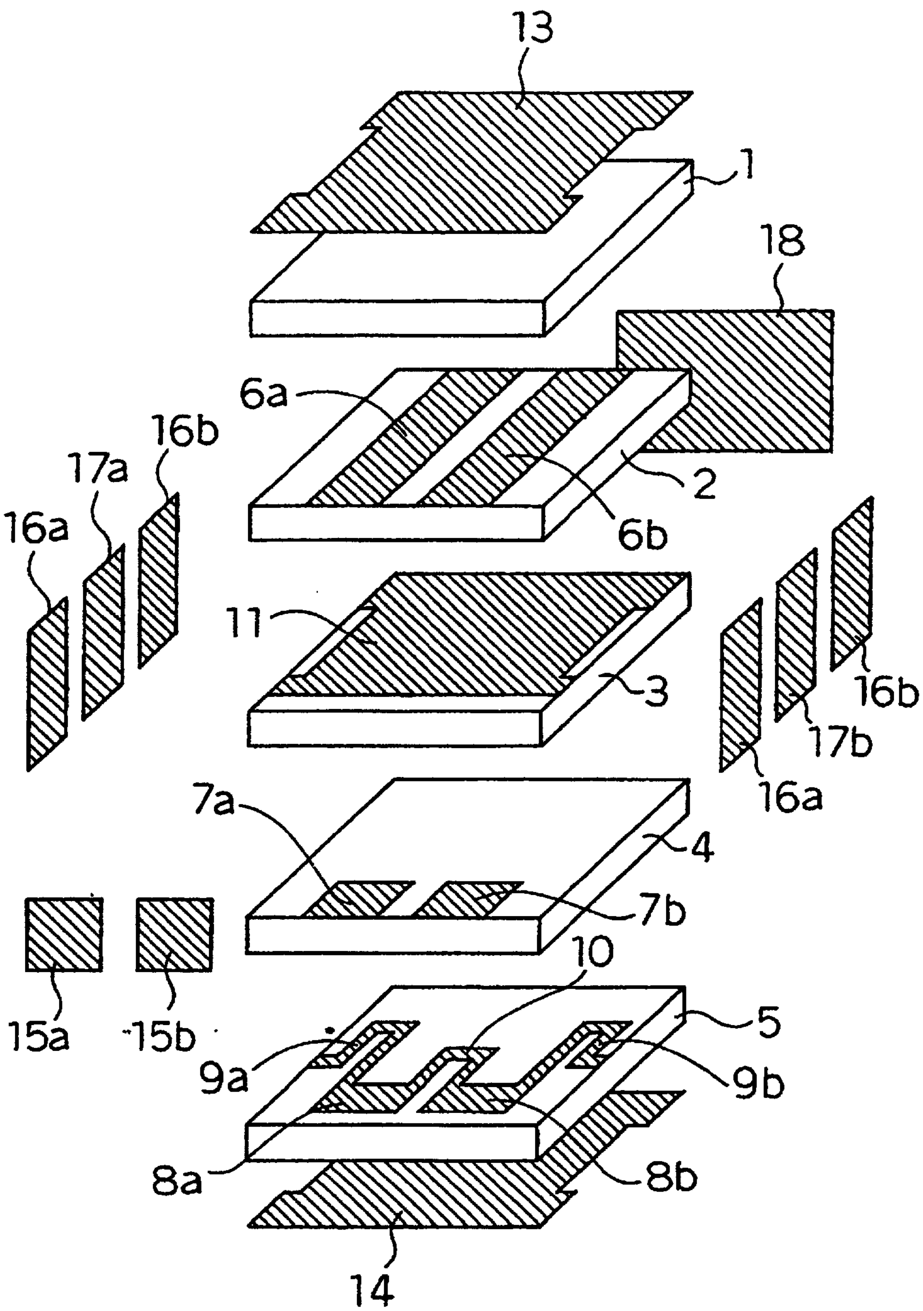
13
1
18
6a
16b
17a
16a
2
6b
11
3
16b
17b
16a
7a
4
7b
10
15a
15b
5
9a
9b
8a
8b
14

Fig. 2

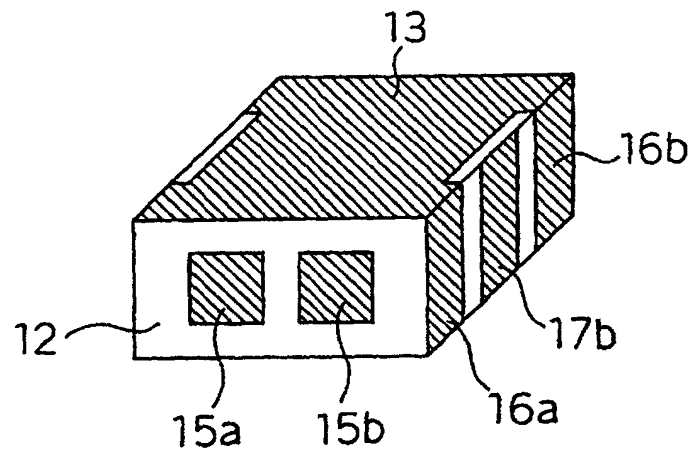
13
16b
12
17b
16a
15a
15b

Fig. 3

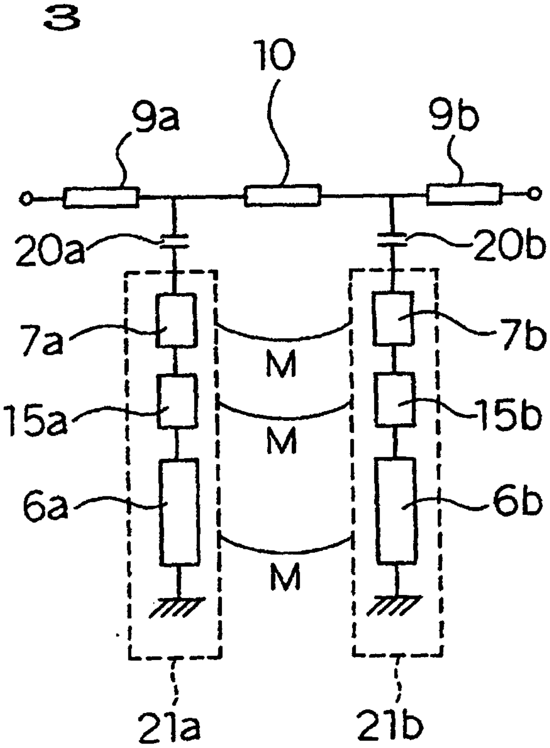
10
9a
9b
20a
20b
7a
7b
M
15a
15b
M
6a
6b
M
21a
21b

Fig. 4

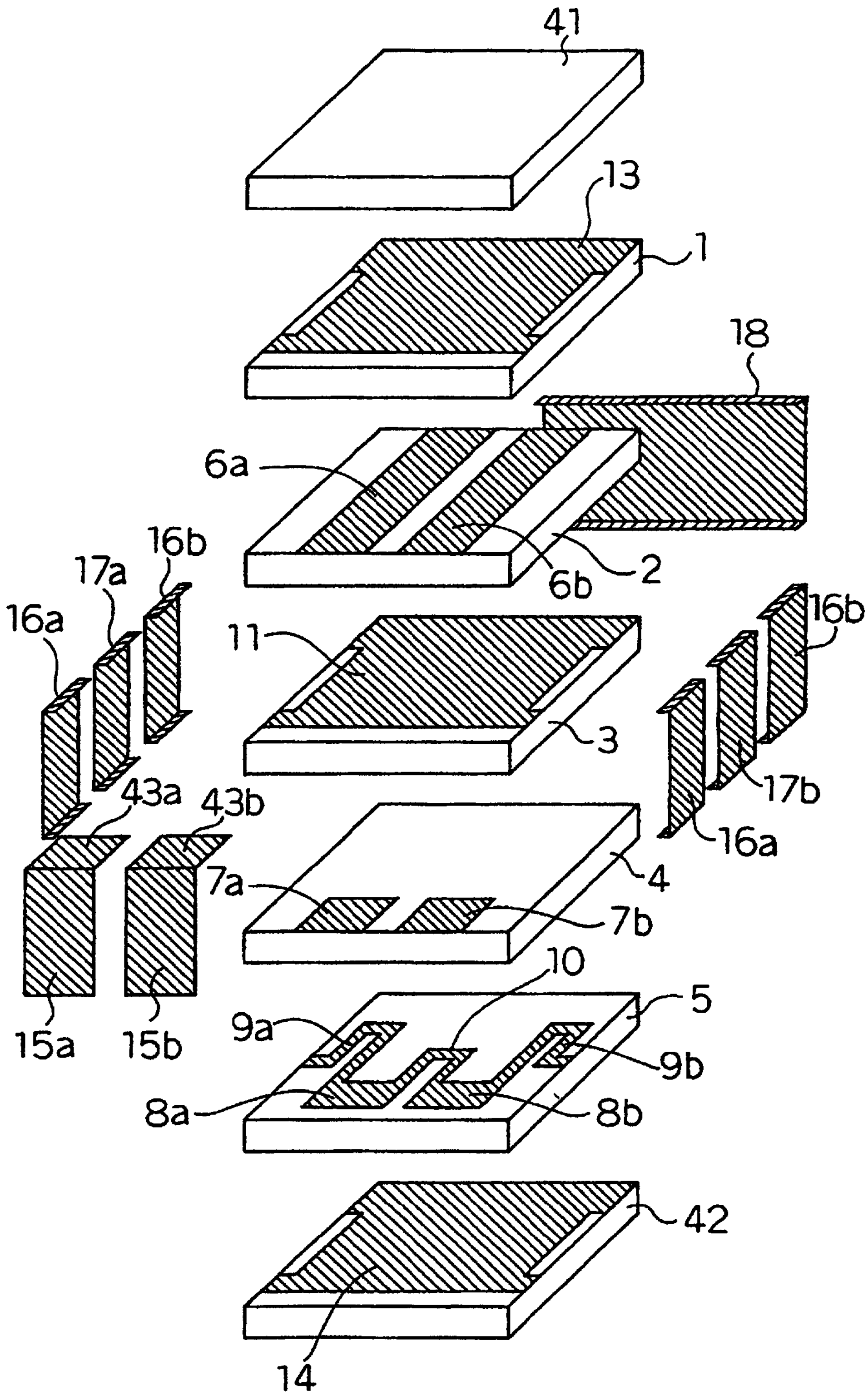
41
13
1
18
6a
16b
17a
16a
6b
2
11
3
16b
17b
16a
43a
43b
7a
4
7b
10
15a
15b
9a
5
9b
8a
8b
42
14

Fig. 5

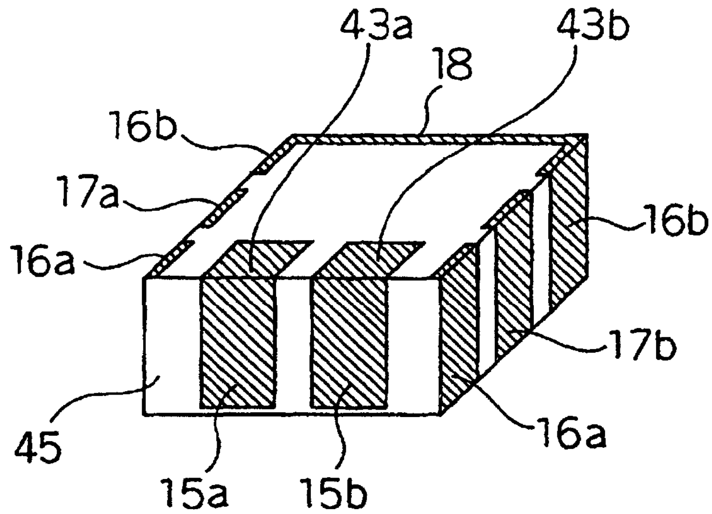
43a
43b
18
16b
17a
16a
16b
17b
45
16a
15a
15b

Fig. 6

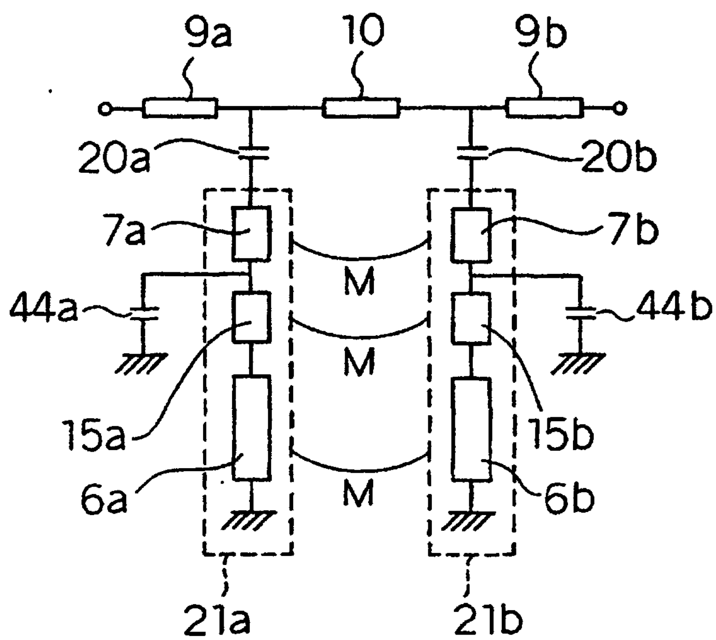
9a
10
9b
20a
20b
7a
7b
M
44a
44b
M
15a
15b
6a
M
6b
21a
21b

Fig. 7

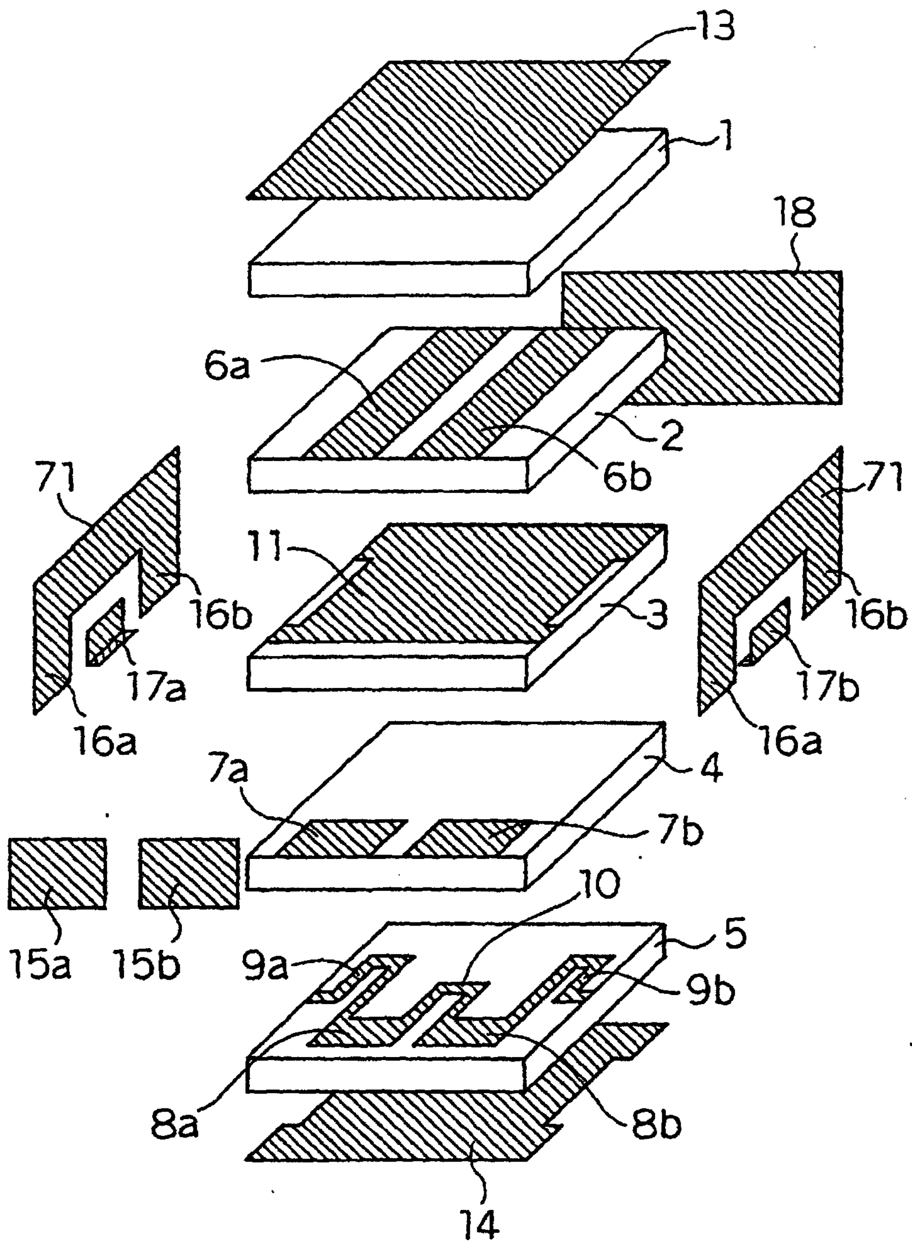
13
1
18
6a
2
6b
71
16b
11
3
17a
16a
17b
7a
4
7b
10
5
15a
15b
9a
9b
8a
8b
14

Fig. 8

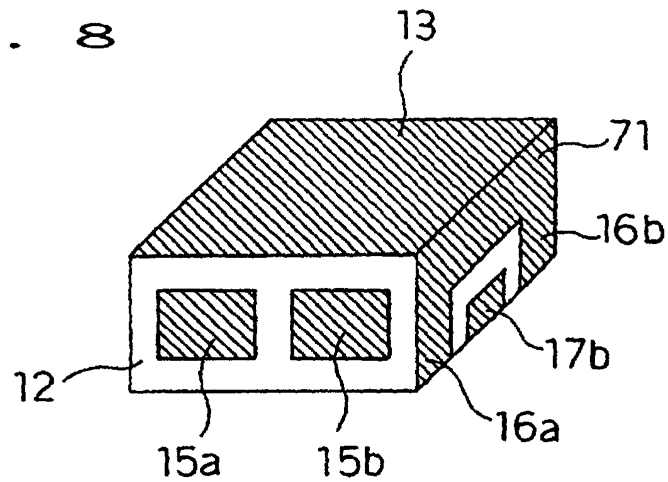
13
71
16b
17b
12
16a
15a
15b

Fig. 9

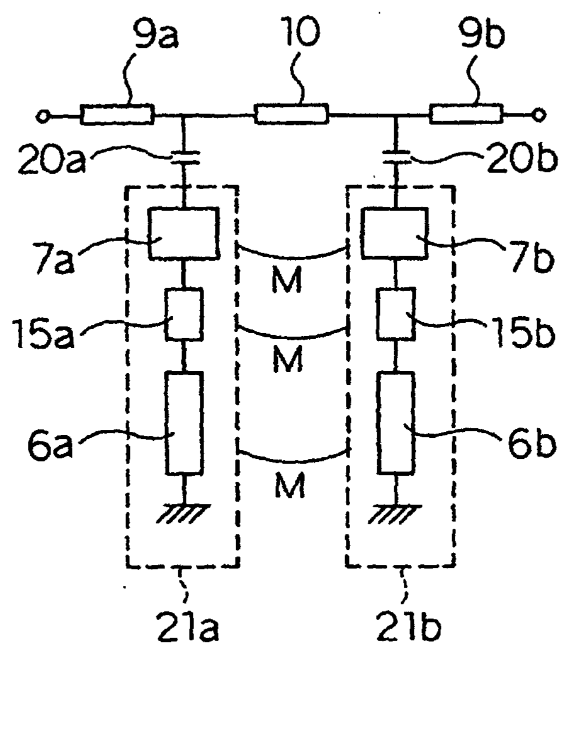
9a
10
9b
20a
20b
7a
7b
M
15a
15b
M
6a
6b
M
21a
21b

Fig. 10

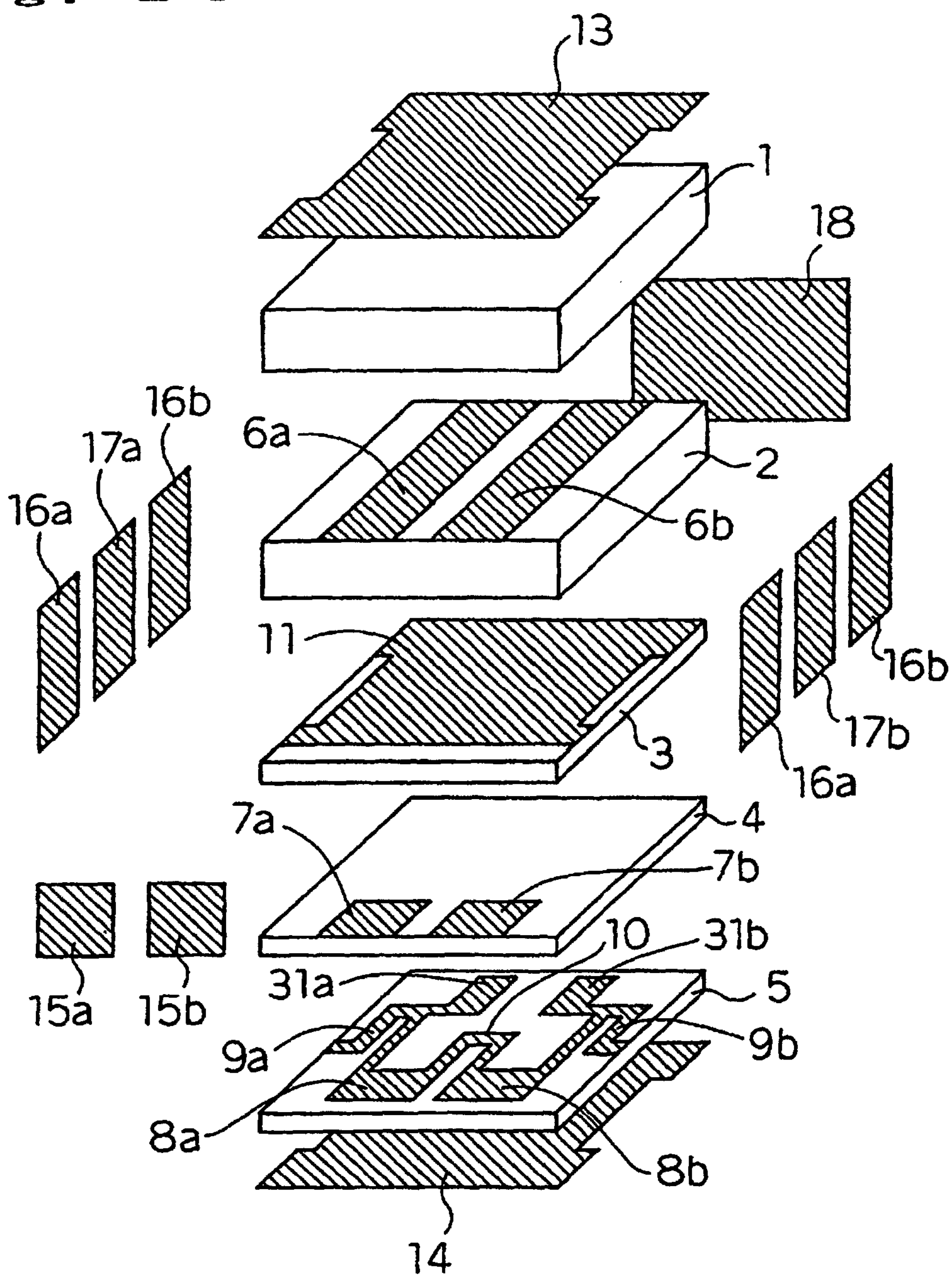
13
1
18
16b
6a
17a
2
16a
6b
11
16b
3
17b
16a
4
7a
7b
15a
15b
10
31b
31a
5
9a
9b
8a
8b
14

Fig. 11

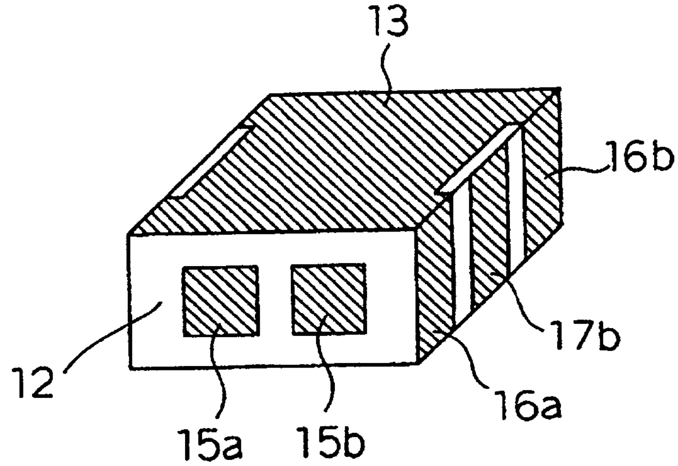
13
16b
17b
12
16a
15a
15b

Fig. 12

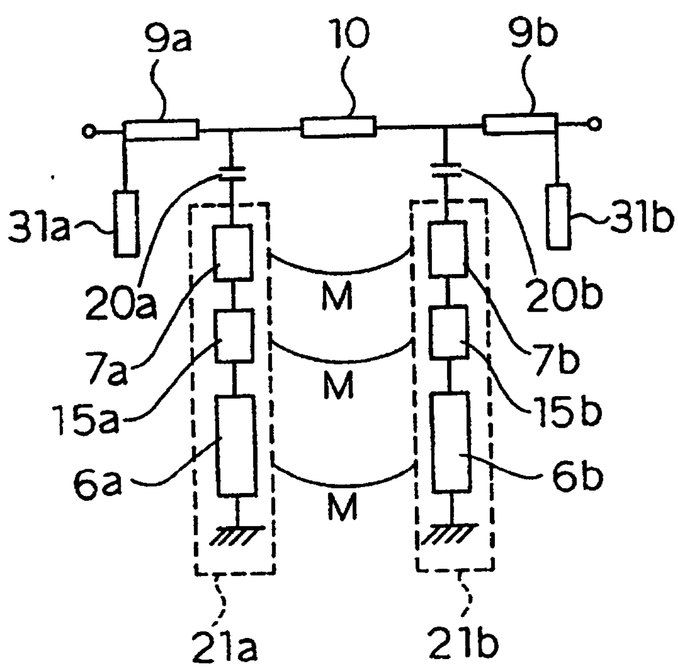
9a
10
9b
31a
31b
20a
20b
M
7a
7b
M
15a
15b
6a
6b
M
21a
21b

Fig. 13 PRIOR ART

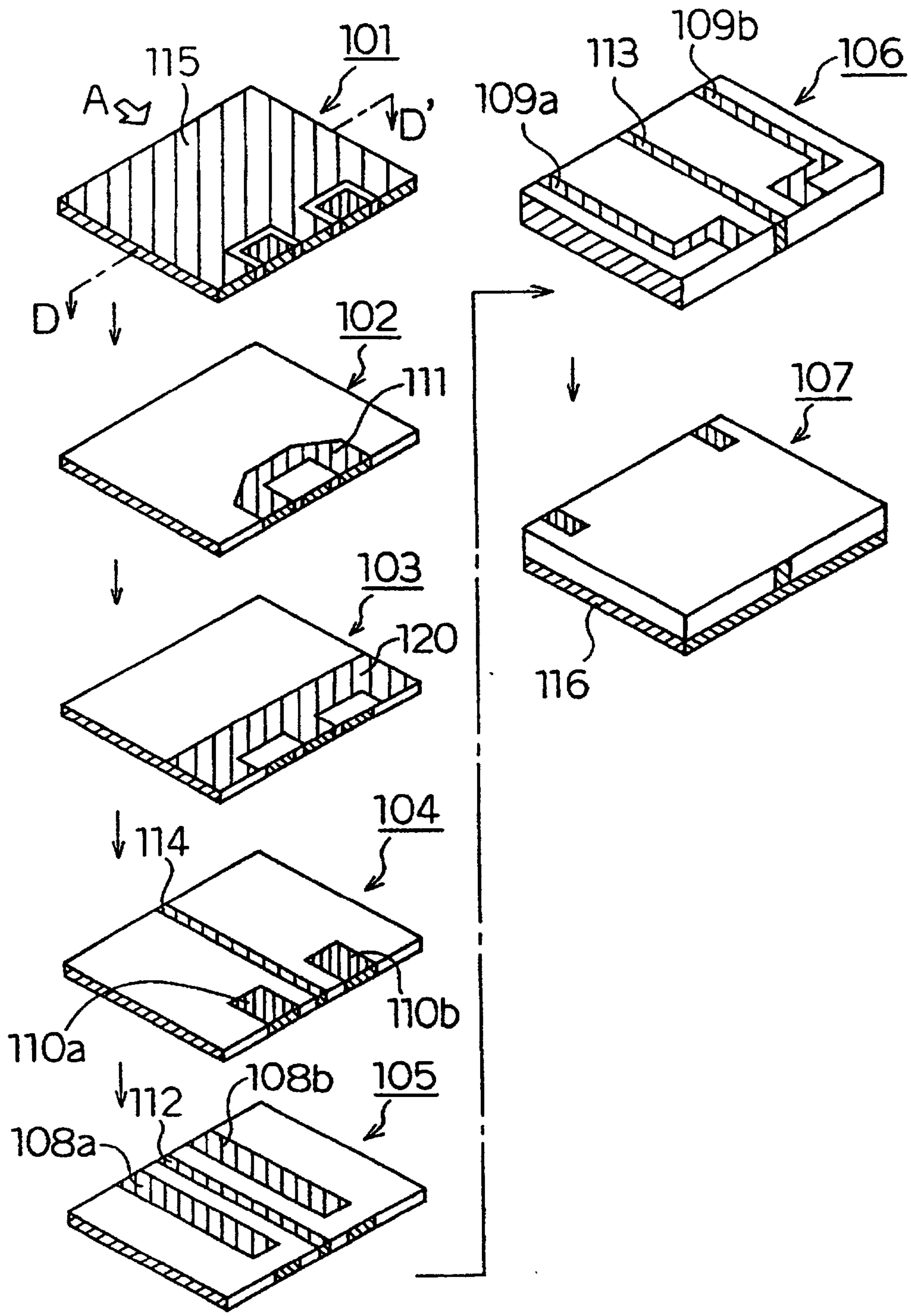

Fig. 14 PRIOR ART

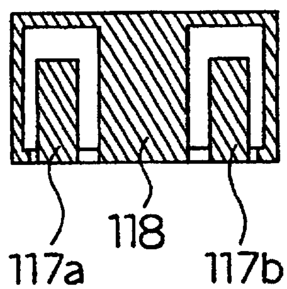

Fig. 15 PRIOR ART

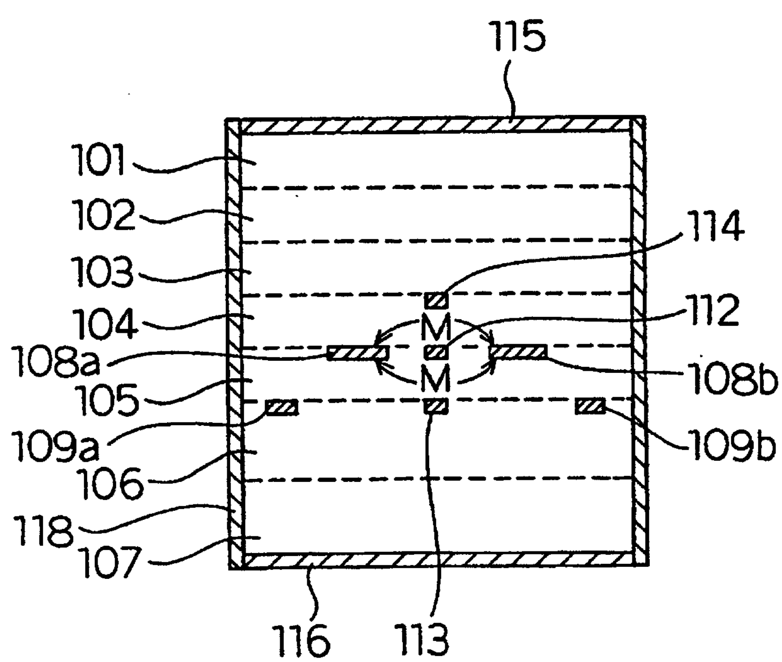

Fig. 16

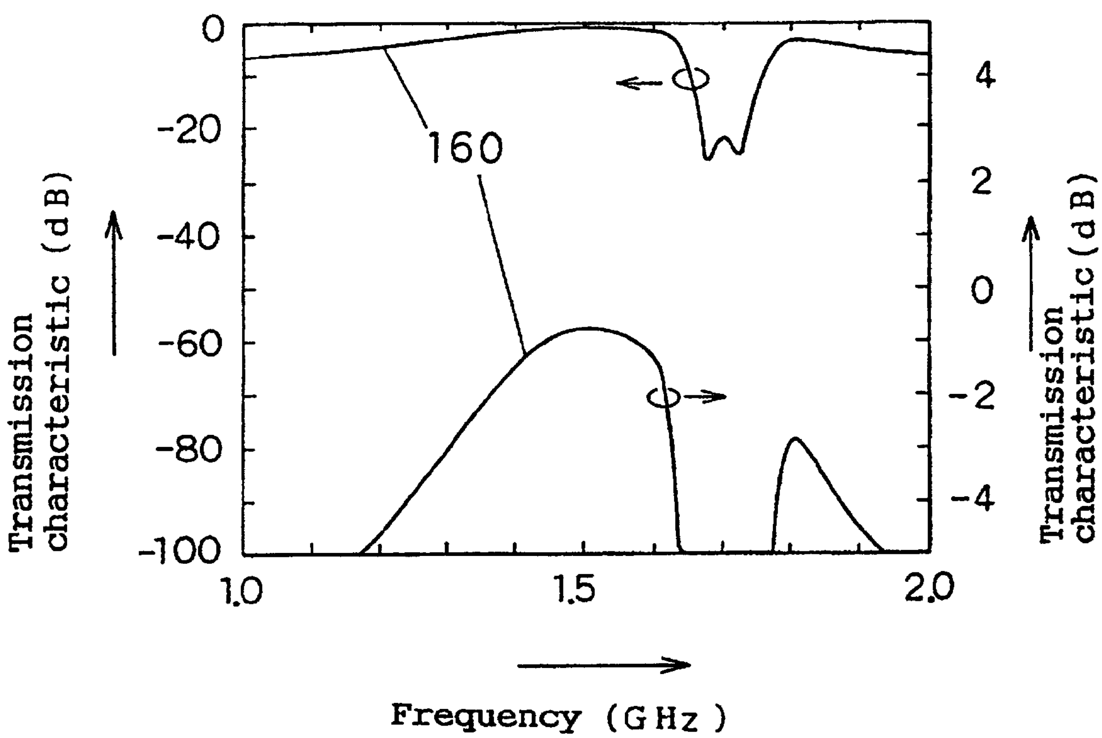
0
-20
-40
-60
-80
-100
1.0
1.5
2.0
4
2
0
-2
-4
160
Transmission characteristic (dB)
Transmission characteristic (dB)
Frequency (GHz)

Fig. 17

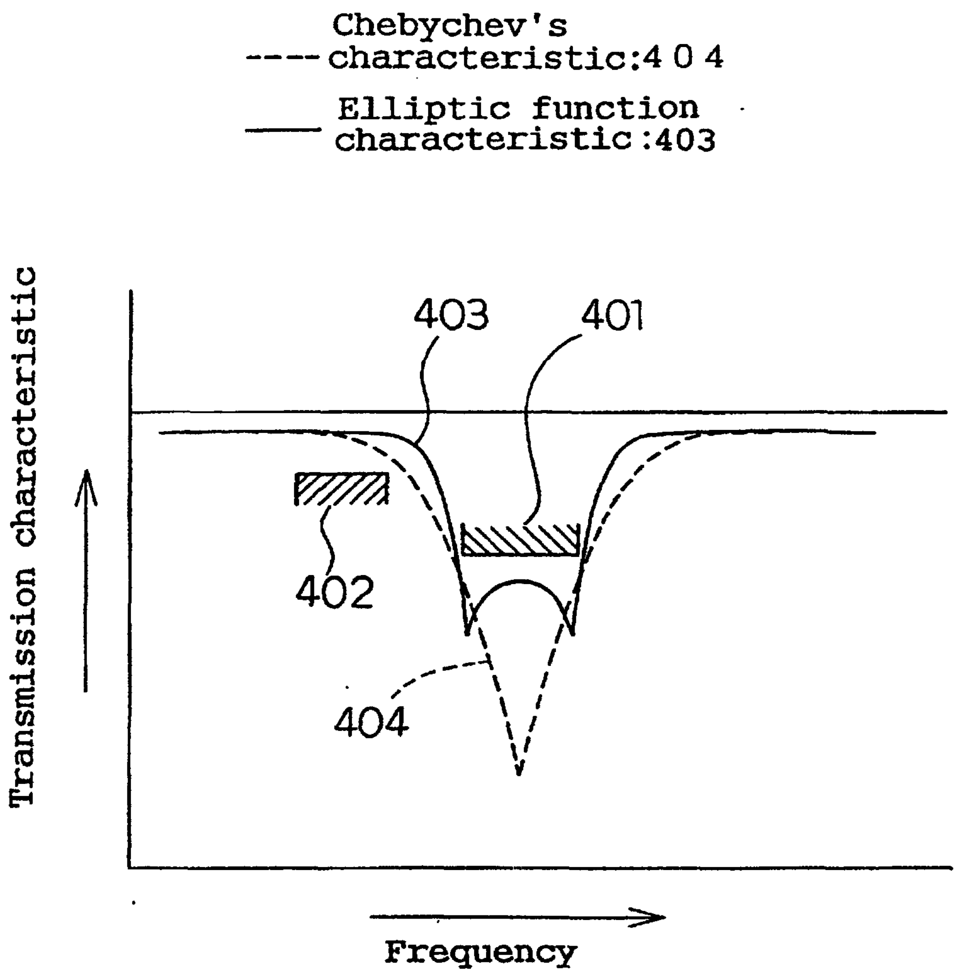
Chebychev's characteristic:4 0 4
Elliptic function characteristic:403
403
401
402
404
Transmission characteristic
Frequency

Fig. 18 A

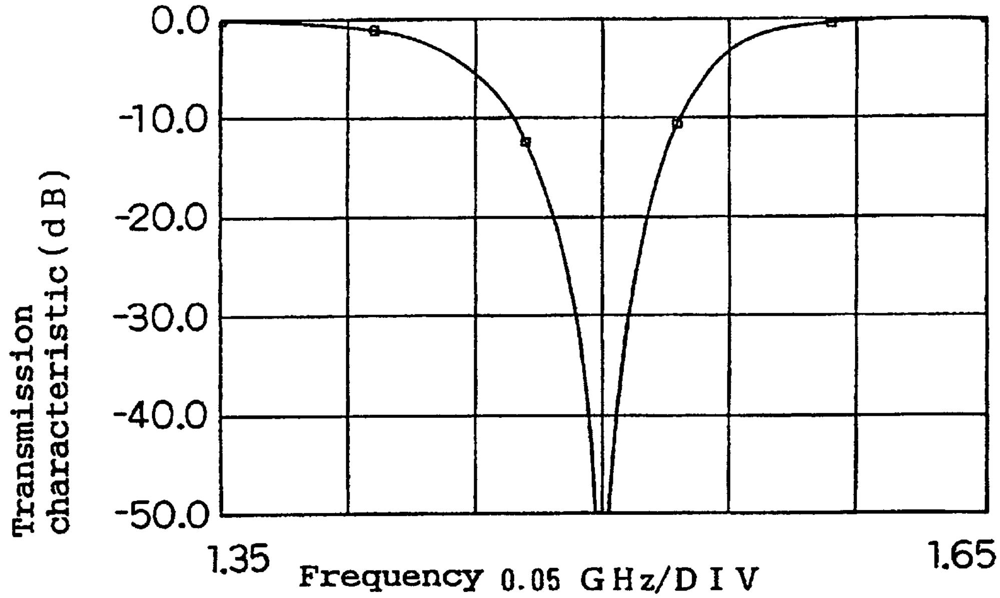

Fig. 18 B

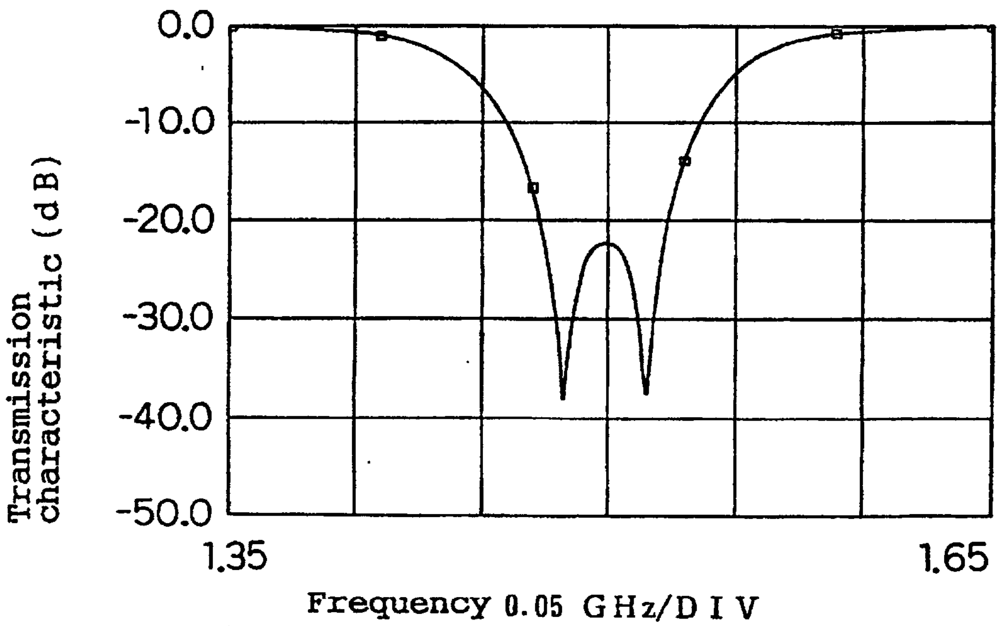

Fig. 18C

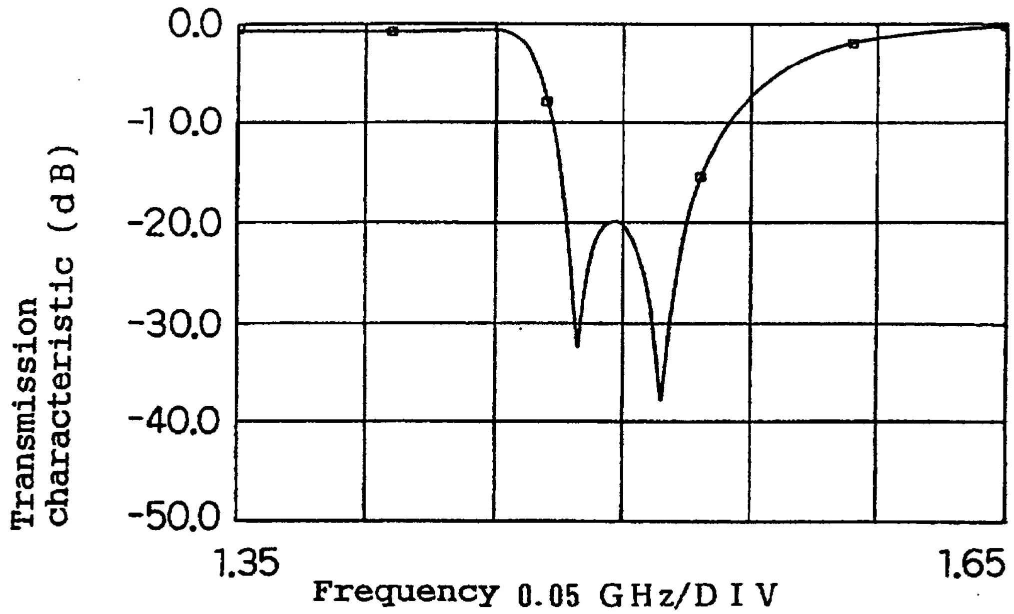

Fig. 18D

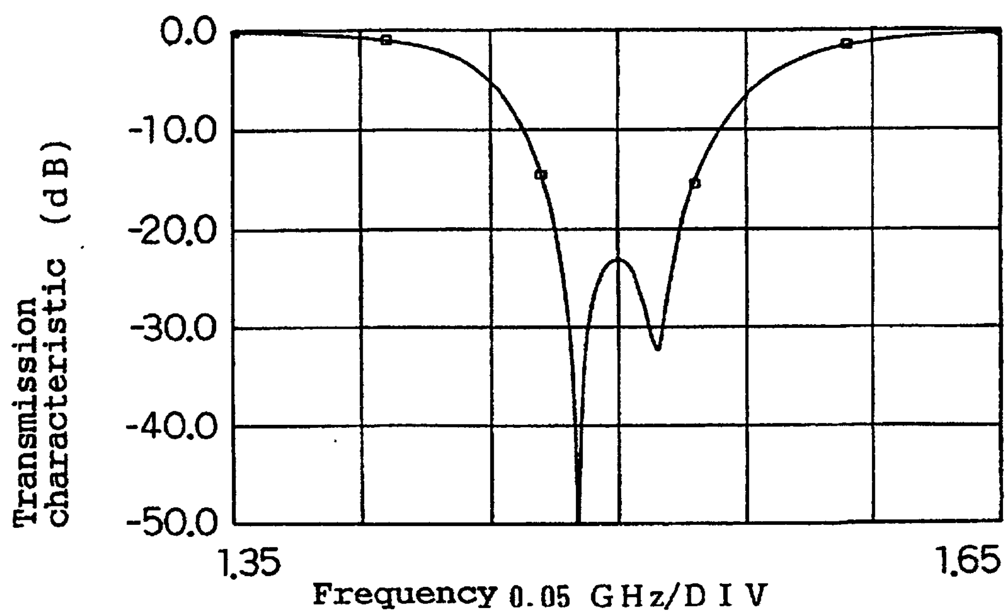

Fig. 18 E

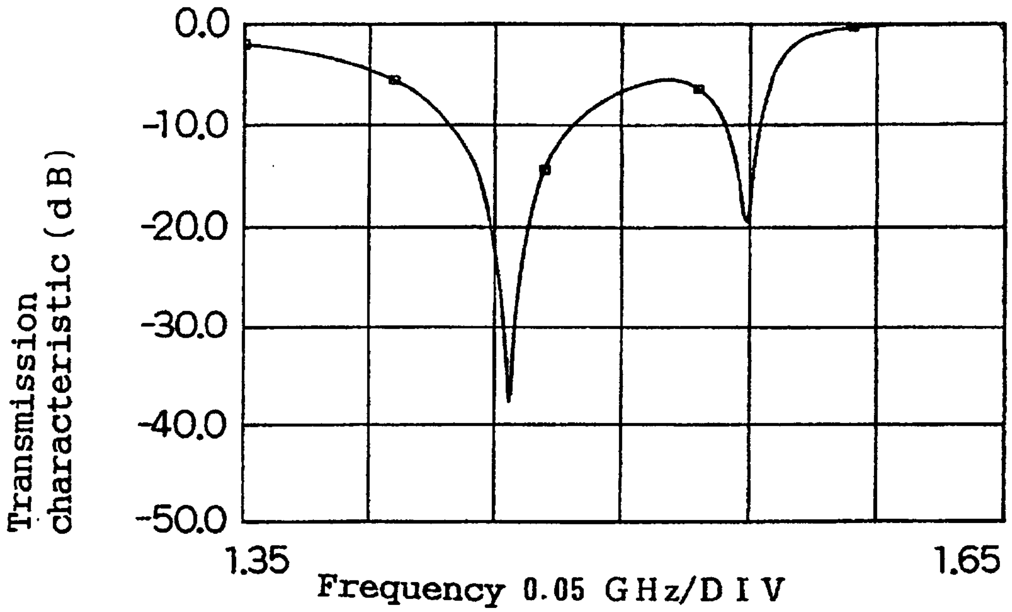

Fig. 18 F